The USEPA's Regional Vulnerability Assessment Program: A Research Strategy for 2001-2006

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Executive Summary

The goal of ORD's Regional Vulnerability Assessment (ReVA) Program is to develop approaches to quantifying regional ecological vulnerabilities so that risk management activities can be targeted and prioritized. ReVA's focus is to develop a set of *methods* that are applicable to the range of data available in regions (e.g., physiography, land use/cover change, change in climate, air pollution, non-indigenous species (NIS), the distribution and condition of resources, and others) and provide information to facilitate decision-making at the regional, watershed, and local scale. Information will be integrated to allow an assessment of the *cumulative* risks associated with multiple stressors on multiple resources, to identify the specific geographic areas of concern, and to evaluate the particular stressors that offer the greatest sources of vulnerability. The application of the tools developed by ReVA should allow decision-makers to put environmental issues in perspective and will provide the spatial context necessary to improve decision making at the watershed and community level. ReVA's pilot study is focusing on the Mid-Atlantic region as part of the Mid-Atlantic Integrated Assessment (MAIA) (a federal, state and local partnership led by USEPA Region 3). In future years, ReVA will move to other regions of the US.

As we have learned through ORD's ten-year involvement with the MAIA, a comprehensive integrated regional assessment involves many steps and incorporates data and research that focus on understanding ecosystem processes at a variety of scales. As MAIA has evolved, five distinct, iterative steps to improving environmental decision-making have emerged: 1) monitoring to establish status and trends, 2) association analyses to suggest probable cause where degradation is observed, 3) prioritization of the role of individual stressors as they affect cumulative impacts and risk of future environmental degradation, 4) analysis of the trade-offs associated with future policy decisions, and 5) development of strategies to restore areas and reduce risk. The Environmental Monitoring and Assessment Program (EMAP) is developing approaches to address steps one and two; ReVA is developing approaches to address steps three and four. Approaches to address step 5 will be developed in a new research program that is under development.

Based on EMAP and other monitoring data, MAIA has identified 5 groups of stressors that are implicated in the decline of ecological condition across the region: 1) land use change and population growth, 2) resource extraction, 3) pollution and pollutants, 4) non-indigenous invasive species, and 5) cumulative impacts from combinations of multiple stressors. Assessment of the risk associated with these stressors requires a regional approach that incorporates forecasts of anticipated distributions of these stressors. Similarly, evaluation of the potential impacts to regional resources requires analysis of the sustainability of goods, services, and other benefits they provide. ReVA will develop exposure models that estimate current and future distributions of the 4 drivers of change and their associated stressors as they relate to endpoints such as native biodiversity, resource productivity, and clean drinking water. Risk of cumulative impacts will be identified in areas where multiple changes are projected. ReVA will assess risk associated with these individual stressors as well as their potential cumulative effects. ReVA will quantify effects associated with anticipated changes (e.g. population growth, air deposition under Clean Air Act amendments) and illustrate trade-offs associated with alternative policy decisions (e.g. limits to growth around major metropolitan centers) through future scenarios analysis.

ReVA's approach is to focus analyses at the regional scale. This effort will complement other ORD research programs that are examining ecological processes at the watershed or community level (e.g., the National Exposure Research Laboratory's (NERL) Multi-media Integrated Modeling System (MIMS) and Basin-scale Assessment for Sustainability of Ecosystems (BASE)). Research over the past 30 years has examined the issue of scale and clearly indicates that ecological processes operate differently at different scales. Further, processes that occur at a higher-level (broader) scale tend to constrain processes at lower-level (finer) scales. For example, the site-specific impacts of non-point source pollution depend on land use and sedimentation occurring upstream as well as regional patterns of geology, topography, and weather. Efforts that attempt to remediate problems at the local scale may thus be ineffective if the influence of these regional scale processes is not recognized. ReVA's research will explore how stressor and exposure patterns influence regional processes and will include: 1) land use change and the influence of socio-economics on urban and rural development as well as regional resource exploitation; 2) the spread of non-indigenous species as it relates to regional development and landscape characteristics; 3) changes in habitat distribution and availability and the implications for population viability and regional biodiversity; 4) cumulative impacts of climate change, NIS, increased development and air pollution; and 5) subregional (i.e., watershed, ecoregion) differences in sensitivity that effect differences in response and thus vulnerability.

While vulnerability analyses will be conducted at the regional scale, we recognize that effective environmental decision-making often occurs at scales below the regional, i.e., local, community, and watershed. To demonstrate how the regional perspective can improve this level of decision-making, ReVA will partner with clients at the state and local scale to develop, demonstrate, and communicate finer-scale applications of the regional assessment information. Specific examples of how the regional context will contribute to these applications include: 1) an increased ability to anticipate timing and distribution of future environmental problems that progress across the landscape (e.g., spread of NIS and increased development pressure); 2) identification of specific areas that are regionally significant because of the presence of rare species, limited habitat (e.g., areas of unfragmented forest), or that provide critical points of connectivity for migratory species (e.g., stopover locations for neotropical migratory birds); 3) an improved understanding of how landscape characteristics can help predict impacts from changes in watershed management (e.g., classification of watersheds to determine total maximum daily loads (TMDLs)); and 4) improved strategic planning for future development through identification of areas that are less sensitive to change (e.g., siting of industrial parks, extraction of mineral and timber resources).

The research tasks needed to achieve ReVA's goal include: 1) improving techniques to interpolate point monitoring data (estimate values between points) and extrapolate the results of finer-scaled effects research (e.g., dose-response studies); 2) developing spatially distributed models of exposure to estimate risk where monitoring data on stressors or resources are lacking; 3) developing new indicators that utilize available data to identify changes in regional scale vulnerability; 4) developing statistical techniques to quantify the probability and uncertainty associated with future shifts in environmental condition resulting from multiple stressors; and 5) exploring techniques to communicate the economic and social costs and benefits of alternative risk reduction activities.

Section 1
Introduction

1.1 Purpose

This document presents the research strategy for the US Environmental Protection Agency (USEPA) Regional Vulnerability Assessment (ReVA) Program. This strategic document provides the context for prioritizing research necessary to conduct and implement the ReVA Program. Individual research plans for the projects comprising the different elements of ReVA have been, or will be developed. These research plans are required to pass peer review before receiving support from the program. This strategy will be updated periodically as needed.

1.2 Background

Until recently, ecological studies and management practices were conducted and implemented at local scales. During the past two decades, however, it has become clear that evaluations of environmental problems and management practices cannot be considered only at local scales. Increasingly, acidic deposition, global climate change, atmospheric contaminant transport, transformation and fate, forest fragmentation, biodiversity loss, and land use changes have been recognized as problems that have to be addressed at broader scales (EPA Science Advisory Board, SAB). Local scale assessments continue to provide valuable information, but expanded knowledge about broader scale problems and their contribution to local scale problems, as well as the cumulative effects of local scale issues, is needed. Unfortunately, many traditional approaches and tools are not applicable at broader scales. Approaches for collecting, analyzing, and interpreting information have to be modified or developed if efficacious management practices are to be implemented to ameliorate local, regional, and global scale problems. Drawing inferences requires more than just aggregating existing local site data (O'Neill et al. 1986).

Multiple stressors and associated stressors affect multiple resources at these broader scales and identifying and partitioning the individual and cumulative effects of stressors across all resources represents a major research challenge (USEPA 1988, National Science and Technology Council 1999a). In addition to addressing this research challenge, a regional approach is also needed to effectively target risk management activities and gain insight into the most cost-effective or socially acceptable ways to address the complex issues associated with multiple stressor - multiple resource interactions (Graham et al. 1991). These research needs were highlighted by the USEPA SAB (1995, 1998b) and were incorporated in the USEPA Office of Research and Development (ORD) Ecological Research Strategy (1998b) as a high priority research area. Regional scale insight is critical if finer scale problems are to be put into perspective and management practices are to be effective.

ReVA is designed to develop approaches that address the latter phases of an integrated ecological assessment, following development of specific assessment questions (problem formulation) and building on available monitoring data, with a focus on integrating and synthesizing information on the spatial patterns of multiple exposures to allow a comparison and prioritization of risks. ReVA is not designed to do complete regional assessments and assumes that assessment endpoints have already been identified and that monitoring data that represent these endpoints are available. As EPA ORD has learned through our ten-year involvement with the Mid-Atlantic Integrated Assessment (MAIA - a federal, state and local partnership led by EPA Region 3), a comprehensive integrated regional assessment involves many steps and incorporates data and research that focus on understanding ecosystem processes at a variety of scales. As MAIA has evolved, five distinct, iterative steps to improving environmental decision-making have emerged: 1) monitoring to establish status and trends; 2) association analyses to suggest probable cause where degradation is observed; 3) prioritization of the role of individual stressors as they affect cumulative impacts and risk of future environmental degradation; 4) analysis of the trade-offs associated with future policy decisions; and 5) development of strategies to restore areas and reduce risk. The Environmental Monitoring and Assessment Program (EMAP) is developing approaches to steps one and two; ReVA is developing approaches to address steps three and four; and approaches to address step five will be developed by a new research program that is under development (Figure 1). ReVA will demonstrate application of these approaches and will provide guidance for this phase of the assessment process, but the full assessment of regional vulnerabilities is primarily the responsibility of regional decision-makers. ReVA is designed to improve the methods and tools available to these decision-makers.

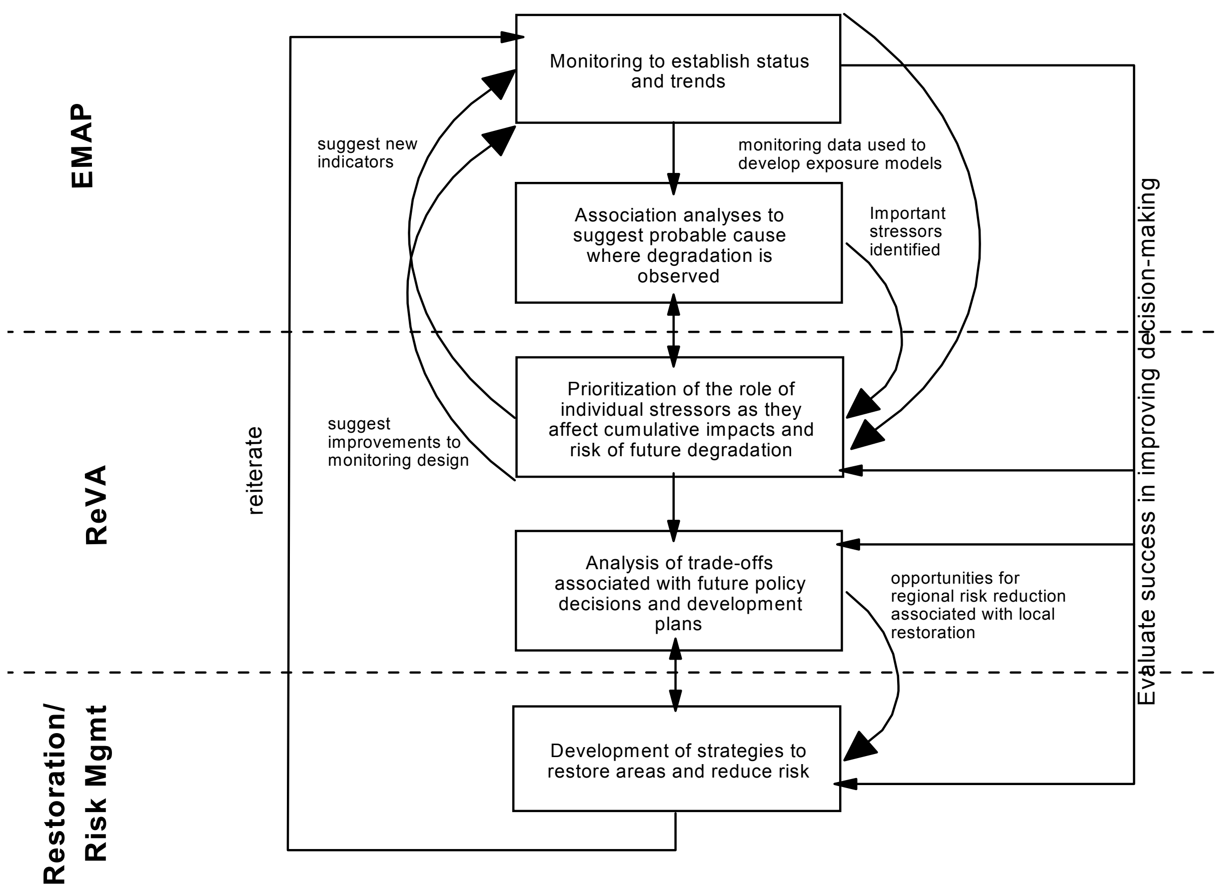


Figure 1. Steps in the integrated assessment process: approaches developed by ORD research programs.

1.3 Integrated Science for Ecosystem Challenges

In 1999, the National Science and Technology Council (NSTC), Committee for the Environment and Natural Resources, Subcommittee on Ecological Systems (CENR/SES) proposed a strategy to address major ecosystem challenges: stresses that affect the integrity of ecosystem structure and function, and the ability of natural and managed systems to provide goods, services, and other benefits to society (NSTC 1999a). These stresses, which often act in concert to produce cumulative effects which are poorly understood, include: 1) changes in land and resource use; 2) introductions of invasive species; 3) inputs of pollutants and excessive nutrients; 4) extreme natural events; and 5) changes in atmospheric and climate conditions. The proposed strategy called for interagency efforts in the area of *Integrated Science for Ecosystem Challenges* (ISEC) to "develop, coordinate and maintain a national research infrastructure to provide the scientific information needed for effective stewardship of the nation's natural resources."

Three strategic priorities were established:

- synthesize existing information and develop new knowledge about the structure, function, and resiliency of habitats and ecosystems;
- improve understanding of the effects of multiple stresses on habitat and the delivery of ecosystem goods and services; and
- provide advanced models and information technologies to improve assessments and forecasts of habitat and ecosystem conditions under alternative policy and management options.

Following the proposal, the CENR/SES developed an implementation plan (NSTC 1999b) that was supported by the Administration and put forward as a new budget initiative. The implementation plan called for $96 million in new funds to enhance ongoing agency and interagency activities in 4 critical areas:

- invasive species, biodiversity, and species decline;
- harmful algal blooms, hypoxia, and eutrophication;
- habitat conservation and ecosystem productivity; and
- information management, monitoring, and integrated assessments.

ORD's ReVA program is supported primarily with funds under the third critical area, habitat conservation and ecosystem productivity. Research under this critical area is designed to include: integrated research on landscape and watershed processes; ecosystem structure and function at the land-water interface; criteria and indicator development; sustainability science; modeling and forecasting responses to multiple stresses; and aquatic habitat assessment.

1.4 Regional Vulnerability

A *region* is defined as a large, multi-state geographic area such as the Mid-Atlantic, Northeast, Southeast, or Pacific Northwest. An EPA Region is a useful representation of a geographic region, because it reflects the size of the geographic area being considered in the ReVA Program and because strategic planning and management decisions are made at this scale.

Vulnerability has multiple elements in its definition but is most simply represented by the probability that future condition will change in a negative direction. We see the ecosystem as a relatively stable configuration of a number of species with the ability to resist and/or recover from the normal array of disturbances such as fire, flood, and drought that it has experienced over its evolutionary history. We assume stability, resiliency, adaptability, and resistance when we extract resources from the system, depend on it to purify wastes, or impose recreational impacts. However, these assumptions are no longer valid when the stresses we impose are outside the range that the organisms have evolved to resist and move that ecological system outside the normal range of variability. Thus, the vulnerability of an ecological system increases as the number, intensity, and frequency of stressors increases.

Vulnerability also must consider the interaction of multiple changes on a system. There is a long and well-documented history of synergistic effects in which one stressor lowers the resistance of the organisms to other stresses (Foran and Ferenc 1999). An example is provided by the high elevation Spruce-Fir forest in the Southern Appalachians. It has been suggested that acid precipitation has lowered the resistance of the trees, permitting an epidemic outbreak of a non-indigenous pest, the balsam woolly adelgid, and the Fraser fir forests are being destroyed (Hain and Arthur 1985). Even though each stressor could be resisted independently, superimposed stressors can cause unexpected unstable reactions. In most cases, we don't have sufficient research information to identify all of the potential synergistic effects, but we can at least point out that the vulnerability of an ecosystem increases as the number of different changes increases. The more different stressors there are, even at sublethal levels, the greater the risk that synergistic effects will occur and cause serious damage. Improved risk assessment of synergistic effects will be a ReVA research focus in outyears (beyond 2006).

Ecosystems are particularly vulnerable to human land use/cover changes - both urban and agricultural. In addition to altering the native ecosystem, land use conversion causes an array of side-effects such as habitat fragmentation, non-point source pollution, and changes in water movement and water quality. Land use conversion both encourages and is influenced by road building - with its own array of environmental impacts (Forman and Alexander 1998). Land use change can also drive changes in air quality with additional vehicular traffic and particulate matter associated with disturbance. Therefore, vulnerability must also consider the socioeconomic drivers that determine the probability that natural ecosystems will be converted to human uses.

In addition to the stressors on regional systems, vulnerability must also consider the sensitivity and adaptability of natural systems being stressed. Some systems may be particularly sensitive to a stressor or to cumulative effects from several stressors. Some of the sensitive resources can be identified from research results, e.g., some plant species are particularly sensitive to ozone, some fish species to chemical stressors, small stream systems to removing riparian vegetation. Other sensitive resources can be deduced - plant species at the northern or southern edge of their distribution are already under climatic stress and may be sensitive to any additional stress.

Vulnerability also must consider the sensitivity or probability of extinction for rare species and rare habitat. Such species and habitats are vulnerable in the sense that the damage is irreparable. There are also unique habitats like wetlands, mountain tops, and caves that support a unique flora and fauna, which must also be considered vulnerable and irreplaceable.

Finally there are ecological resources that are considered vulnerable which provide society with valued goods, services and other benefits. This may involve resource extraction (e.g., forests and fisheries), recreation (e.g., forests and lakes), waste treatment, and nutrient recycling. Vulnerable ecological resources in this category are critical because damage to them can have an immediate impact on society.

Regional vulnerability is many things. It is rarity, synergy, sensitivity, and spatial context. No single question or approach will suffice. Regional vulnerability analysis will draw on many sources of data, will explore many different assessment methods, and will enable decision-makers to ask many different questions.

Section 2
Regional Vulnerability Assessment (ReVA) Program

2.1 What is ReVA?

ReVA is a research program to develop and demonstrate approaches and tools for quantifying, assessing and communicating ecological vulnerabilities at regional scales so that risk management activities at all scales can be prioritized and targeted. Building on available monitoring data (e.g., EMAP, state monitoring data, regional spatial data provided by other agencies, newly available remotely sensed data), ReVA will explore and evaluate techniques to predict and compare the spatial patterns of multiple stressor exposures and will thus contribute to regional ecological risk assessments conducted through the EPA National Center for Environmental Assessments (NCEA), Regional and Program Offices, and other agencies. ReVA will develop approaches to integrate spatially explicit information on resource sensitivity and condition, and current and future stressor distributions, with associated social values to inform environmental decision-making.

2.2 Goal and Objectives

The goal of ReVA is to develop and demonstrate approaches to comprehensive, regional-scale assessment that effectively inform decision-makers of the severity, extent, distribution, and uncertainty of current and projected environmental risks.

ReVA's objectives represent the sequential steps needed to achieve this goal:

1. Provide regional-scale, spatially explicit information on the extent and distribution of both stressors and sensitive ecological resources;
2. Develop and evaluate techniques to integrate information on exposure and effects so that ecological risk due to multiple environmental changes can be assessed and compared, and management actions prioritized;
3. Project consequences of potential environmental changes and risk management strategies under alternative future scenarios;
4. Effectively communicate economic and quality of life trade-offs associated with alternative environmental policies;
5. Develop techniques to prioritize areas for ecological risk reduction; and
6. Identify information gaps and recommend actions to improve monitoring and focus research.

2.3 ReVA's Research Hypotheses

ReVA's working hypotheses or assumptions are:

- Spatial connections (upstream-downstream, transportation network, shortest air distance) are important in determining the total ramifications of local human activities. Therefore, cumulative ecological condition over large regions is related to large scale patterns as well as small scale decisions.
- Spatial variability reduces the efficiency of bottom up approaches (and increases the efficiency of top down approaches) when assessing ecological condition over large regions.
- Sustainability can only be achieved by maintaining regional variability. Some areas must be reserved to maintain regional biodiversity. Some areas are vulnerable to human disturbance.

Additional hypotheses that are being tested in ReVA include:

- Regional environmental and socio-economic data are available at various spatial scales that can help decision makers prioritize risk reduction activities.
- Modern methods of organizing, presenting and analyzing these data can make them more useful and more valuable for purposes of making risk management decisions.
- Efficient data management and retrieval systems and analytical and presentation software can make regional environmental and socio-economic data available to many decision-makers at an acceptable level of spatial disaggregation and at an acceptable cost.
- Because the types of data and decision-support software needed are relatively uniform from region to region, there are significant economies of scale in developing regional ecosystem vulnerability indicators that make the long-term payoff from investing in up-front data/software development worthwhile.

2.4 ReVA and EPA's Ecological Research Strategy

There are six questions, described in the EPA ORD Ecological Research Strategy (USEPA 1998b), that guide the ReVA research:

1. What are the most effective ways to identify and describe the current distributions of stressors (both natural and anthropogenic) and ecological resources in a region?
2. What are the most appropriate models to quantify the relationships between exposure and effects at regional scales?
3. How can available data on stressor and ecological resource distributions be used to quantitatively estimate exposures at regional scales?
4. How should regional risk assessments deal with cascading exposure and effect phenomena?
5. How can self-consistent, alternative future regional exposure scenarios be constructed, taking into account likely linkages among social and economic drivers in a region?
6. How can ecological outcomes best be linked to human uses and values in integrated feedback loops, rather than simply as unidirectional effects of human activity?

The first three questions will be addressed in the first phase of ReVA research. The last three questions will be addressed in outyears and provide future reserach directions beyond this strategy. Specific research tasks (listed in Appendix 1) will address various aspects of these six questions. The synthesis of the results of all tasks will allow an evaluation of the most promising available technologies and will guide the development of new monitoring and assessment techniques that are better suited to addressing emerging environmental issues.

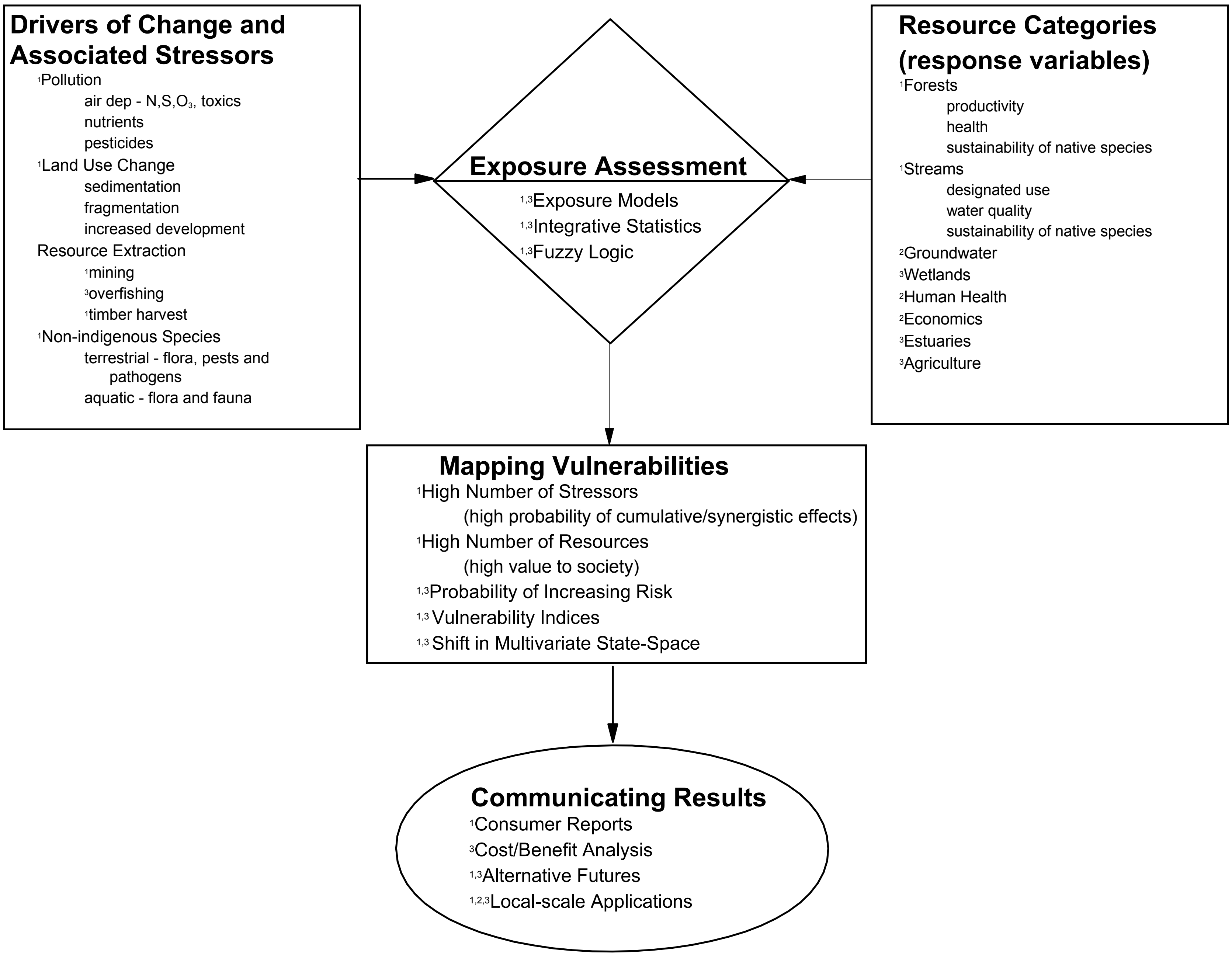
2.5 ReVA as the Second Phase in an Integrated Ecological Assessment

ReVA is designed to develop and evaluate methods to synthesize available information on the distribution of stressors and sensitive ecological resources. It contributes to linking assessment endpoints identified by regional stakeholders with regional stressors. Monitoring networks are established to determine status and trends in these endpoints. Within the MAIA, broad assessment endpoints have been established by "resource groups" (i.e., landscapes, forests, streams, estuaries) and initial condition reports have been completed or are underway (Jones et al. 1997, USEPA 1998a, USEPA 2000, USDA Forest Service in press). Approaches to evaluating risk management alternatives for these assessment endpoints will be demonstrated by ReVA (Figure 2).

Four major drivers of change and their associated stressors have emerged from an evaluation of regional monitoring and assessment activities (e.g., EMAP and state monitoring programs) conducted in the Mid-Atlantic region over the past 5 years. These drivers of change are:

1. Land-Use Change and Population Growth;
2. Resource Extraction (including over-fishing of both fin and shellfish, timber harvest, and mining);
3. Pollution (including urban non-point source pollution, agricultural runoff, atmospheric deposition); and
4. Non-indigenous Species (this includes not only pests and pathogens, but also introduced species that are desired and managed for society such as rainbow or brown trout).

A fifth category of cumulative effects has also been implicated in the degradation of some ecosystems (USDA Forest Service in press). ReVA will contribute to addressing questions related to these five large-scale environmental changes by focusing research to map, model, assess, and compare exposures at the regional scale. These stressor categories are consistent with those identified by the NSTC (1999a) as priority areas for research.



[1]Research underway, expected completion for Phase 1
[2]Research underway, expected completion for Phase 2
[3]Research needed, desired for Phase 2

Figure 2. Current and planned ReVA research.

Section 3
ReVA Strategies

The ReVA strategies support the goal and objectives, and address the research questions and regional themes. The ReVA strategies are:

1. Use a phased approach for implementing ReVA, with Phase One focusing on integrating available information to demonstrate the proof of concept and to identify needed research to assess ecological vulnerability at regional scales.
2. In Phase Two, expand the scope of research to include additional stressors and response variables and refine the integration techniques through application to this broader array of information.
3. Initiate the pilot in the Mid-Atlantic region because it complements, and builds on, the EMAP Program, the MAIA geographic initiative (Figure 3), previous landscape analyses and results, and can contribute to EPA Region 3 strategic planning efforts and management decisions. Continued ORD participation in MAIA also provides the opportunity to refine the Ecological Risk Assessment Guidelines (USEPA 1998) for application to regional scale priority-setting assessments.
4. Develop the ReVA approaches and tools and demonstrate their application at the regional, watershed, and local scale in partnerships with clients. Utilize client partnerships to facilitate technology transfer.
5. Initiate studies in other regions to test the applicability of the methods and approaches in other areas and repeat the process.

ReVA's unique focus is the spatially explicit, regional-scale viewpoint that builds on the pioneering work of EPA's Landscape Sciences Program in developing new assessment techniques (Jones et al. 1997). ReVA is a cross-ORD program that also partners with other federal and state agencies to bring together the best available data and research capabilities to determine how to do regional scale comparative risk assessments. ReVA is intended to develop and demonstrate approaches for regional-scale assessments that can be implemented across the country using methods developed in our pilot study region (the Mid-Atlantic). Therefore, the methods need to have the flexibility to be used in other regions. This means that analyses must use data that are available in each region (i.e., be flexible in input), and models and information must be at the appropriate scale. As such, ReVA will identify gaps in our ability to conduct comprehensive regional scale assessments and will thus guide improvements in monitoring and help identify future research needs.

Work within a second region is expected to begin in FY03-04. This will allow a test of the approaches developed in the mid-Atlantic region, and further refinement of the vulnerability assessment technology. Selection of the second region will be based on the following criteria: 1) data availability (regional-scale, spatially explicit) - ReVA will work with EPA's Office Of Environmental Information (OEI) to identify data-rich regions; 2) availability of a team within the region to work with ReVA scientists (to provide feedback and to facilitate technology transfer); 3) different environmental issues (a test of the applicability of the approach); and 4) client interest (ideally, decision-makers who are interested in what these approaches can add to the process of evaluating and synthesizing environmental data towards improved environmental decision-making).

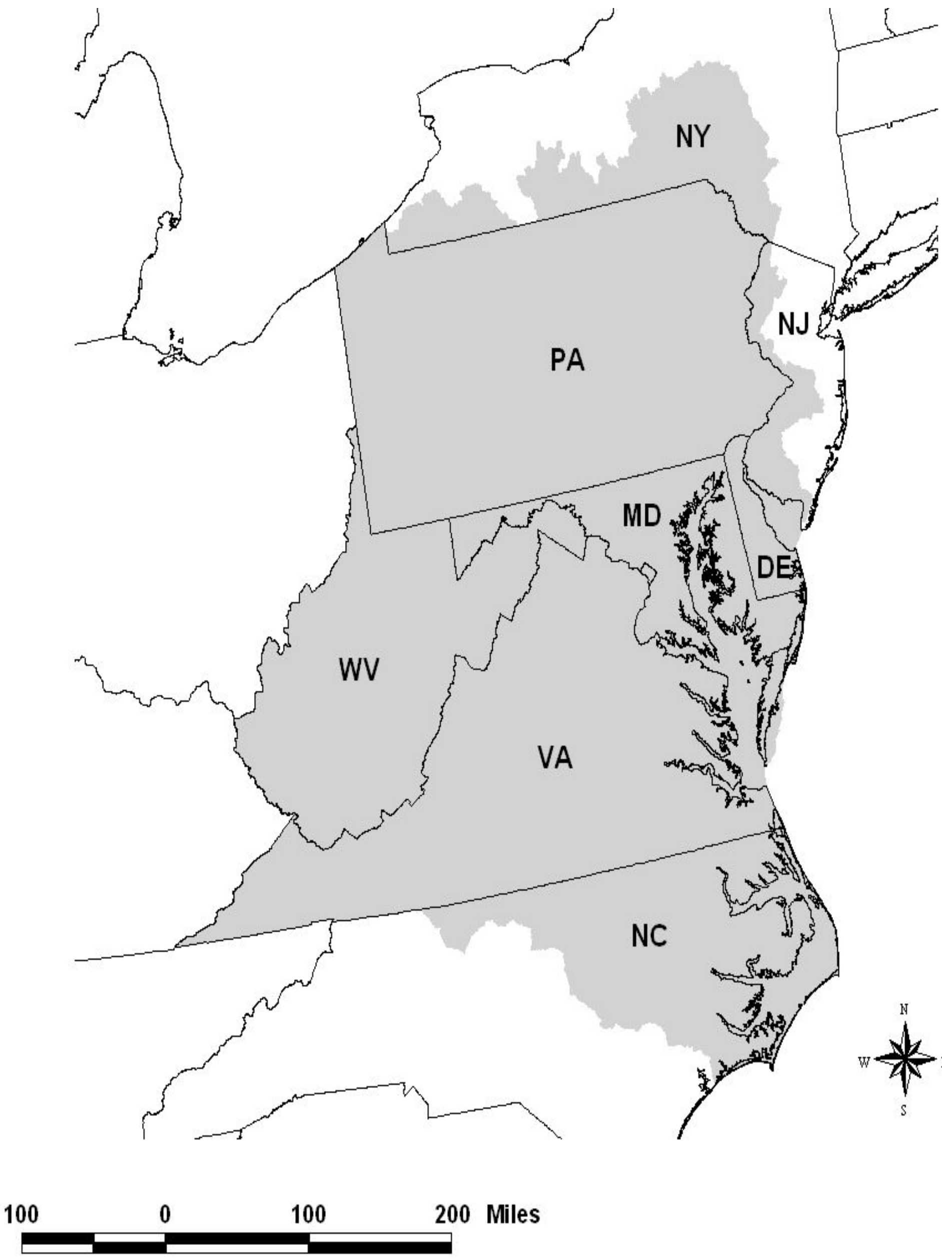


Figure 3. The Mid-Atlantic Integrated Assessment (MAIA) study area.

Section 4
General Approach

One of the ReVA strategies is to use a phased approach (Table 1). To demonstrate a proof-of-concept within a reasonable time frame, Phase One efforts will focus primarily on existing data and models or those that are already under development. Research priorities for the Phase One assessment are to develop techniques needed to use existing data in assessing regional vulnerability (e.g., interpolating point data, combining disparate data) and integrating the information to compare risk among individual stressors (e.g., developing statistical techniques to integrate spatial data and to quantify error and uncertainty associated with multiple stressor impacts on multiple ecological resources). Future projections of land use change and associated effects will also be considered in Phase One.

Phase Two research priorities will focus on expanding the range of resources (endpoints) assessed (e.g., human health, economic systems), identifying thresholds associated with various exposures, refining the integration techniques to better quantify relative risks, and addressing research gaps identified in the Phase One assessment. Future scenarios developed for the Phase Two assessment will include land use change projections as well as changes in emissions and other chemical loadings, projected spread of non-indigenous species, and projected changes in regional weather patterns. The Phase Two assessment will be completed in 2006 if funding for ReVA continues at the same level.

ReVA is designed to improve environmental decision-making by putting regional scale issues (see stressor categories above; Figure 2) in perspective. Vulnerability, as discussed earlier, depends on the co-occurrence of stressors, along with their sequence and magnitude, and variation in the sensitivity of resources. ReVA's approach to assessing vulnerability will proceed by first mapping stressors, sensitive resources, and surrogate indicators of exposure (e.g., landscape indicators such as fragmentation, agriculture on steep slopes, etc.), then integrating this information to map vulnerabilities, and finally, assessing the risk of impacts to valued resources (Figure 4). Through the development of alternative future scenarios, ReVA will ideally illustrate how policy decisions and the associated changes in vulnerability, affect our quality of life. This illustration will help decision-makers evaluate the trade-offs associated with alternative policy choices.

This research strategy is intended to provide the reader with a better understanding of the concepts and strategic approaches underlying ReVA and to highlight research priorities. The general elements or steps involved in implementing the ReVA approach are discussed below. Specific research plans and projects will be formulated to accomplish the various activities described in Figure 2. Additional detail, specific research proposed, schedule, deliverables, and quality assurance will be provided in the individual research plans. Individual research plans must be peer reviewed and approved by the Associate Director for Ecology for each EPA lab/center, other appropriate agency manager or university official. Relevancy of the individual research projects will be determined by the ReVA Steering Committee and the ReVA Planning Committee (see section on Management Structure). Research tasks will be prioritized considering the following criteria: 1) direct linkages to ReVA's objectives or deliverables; 2) linkages to other ReVA tasks; 3) adherence to quality assurance and metadata standards; 4) timeline and needed outyear support; 5) plans for evaluating research results; 6) applicability to other regions; 7) planned technology transfer; and 8) client interest (see Appendix A for proposed task description format). ReVA will not develop an overall research plan but will periodically update this strategy as the program and issues evolve.

Table 1. Phased Approach Strategy.

Phase	Type of Assessment	Endpoints	Stressors	Future Scenarios	Research Priorities
1	Comparative (high number of stressors=high probability of cumulative effects, etc.)	Forests Streams	Pollution (atmospheric deposition, non-point source, agricultural) Land use change Resource extraction Non-indigenous species	Land use change Atmospheric deposition under proposed policy changes, e.g. “Clear Skies” Initiative	Using available data and models Exposure models Integrating information
2	Relative Risk (estimates of probability of crossing threshold)	Forests Streams Estuaries Agriculture Groundwater Human Health Economics	Same as above, but more detail	Land use change Spread of NIS Changes in emissions Changes in demographics/ consumption/ resource extraction Changes in agricultural practices	Integrating data and models Identifying thresholds Communicating results Determining applicability of models to other regions

4.1 Mapping Exposures

4.1.1 Step one

The first step in ReVA will be the development of spatial data sets for the Mid-Atlantic assessment area (Figure 3). This will involve all relevant data that are 1) available for the entire region, and 2) can be represented spatially, i.e., a value for each point on the regional map. Spatially explicit data are required to compare risk across the entire region (Hunsaker et al. 1992). The data will include infrastructure (e.g., roads), stressors (e.g., atmospheric deposition, Chang et al. 1987, and chemical inputs, USDA 1996), landscape characterization data (e.g., Jones et al. 1996), sensitive resources (e.g., wetlands) and ecological endpoints (e.g., avian biodiversity, Flather et al. 1992). Spatial data will be retained at the finest resolution available. This will keep options open for reporting assessments at a variety of spatial units (O’Neill et al. 1997). Developing the spatial databases involves addressing three important issues: 1) which data to include; 2) reaggregation of data into consistent reporting units; and 3) how to estimate and retain the uncertainties in the data.

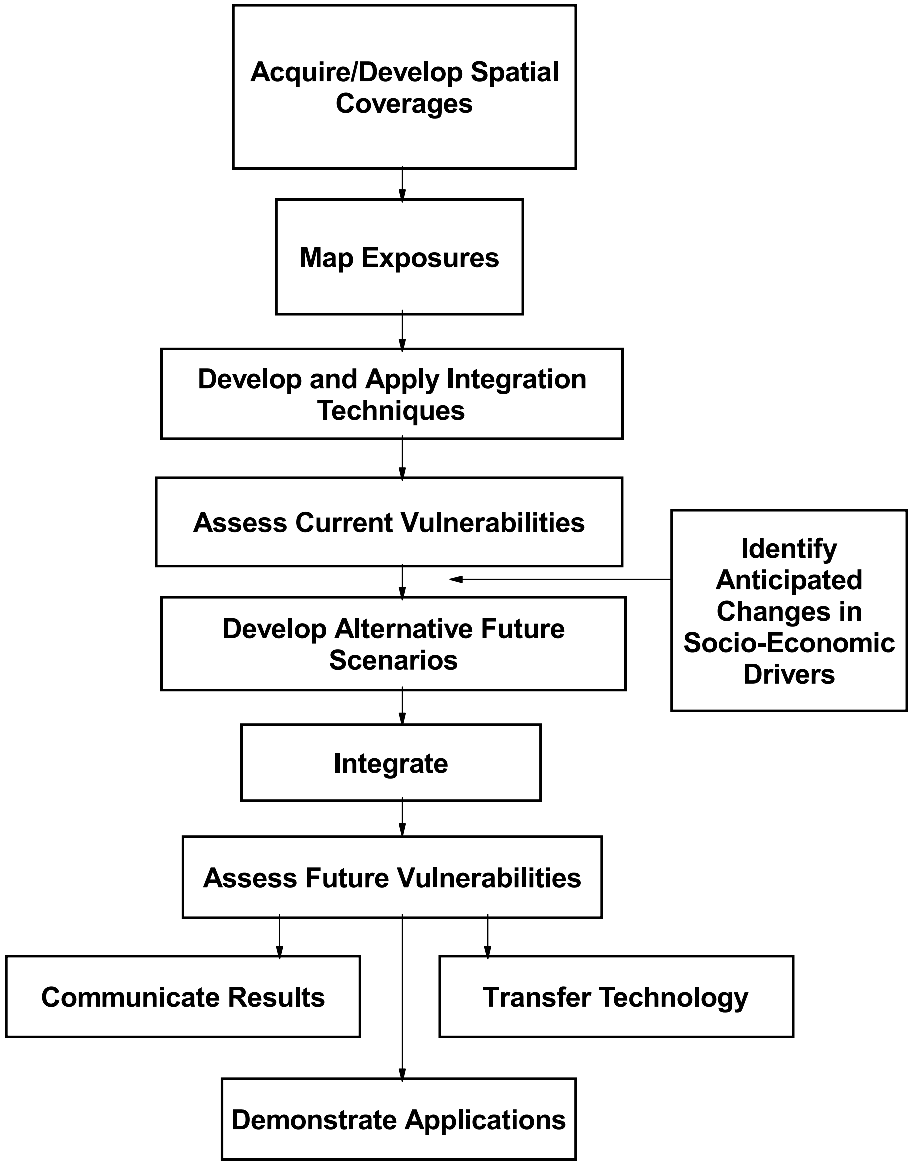


Figure 4. Steps in the phase One Assessment.

Recent research reported in the Landscape Atlas (Jones et al. 1997), the ReVA Stressor Atlas (Lunetta et al. 1999), and the Index of Watershed Indicators (IWI) (http://www.epa.gov/iwi/) indicate that comprehensive regional databases exist for a surprising number of environmental stressors and ecological resources. The emphasis in ReVA will be on utilizing the wealth of available data. Collection of new data will not be emphasized, particularly for the Phase One assessment.

Where critical gaps exist, ReVA will conduct indicator research. For example, none of the current landscape indicators address distance between patches. Since interpatch distance is known to be critical to the impact of habitat fragmentation on wildlife, the new indicator fills a critical gap (Keitt et al. 1997, Barabasi and Reka 1999, Sutherland et al. 2000). This research will be conducted as a joint project of ReVA and the Landscape Sciences Program (NERL, Environmental Sciences Division, ESD).

Some indicators will be direct measures of stress, such as projected land development or pesticide concentrations in streams. Other indicators will be the output of models, such as sulfur dioxide concentrations or nutrient loadings calculated from watershed properties (Hunsaker et al. 1992). Still other indicators will be extrapolations from finer-scaled mechanistic studies (Rastetter et al. 1991). Surrogate indicators of exposure (e.g., fragmentation indices, agriculture on steep slopes) and other metrics (e.g., human use index) from the landscape sciences will supplement the existing information on stressors and allow a more comprehensive view of regional vulnerability.

All measurements have associated uncertainty or measurement error. There are at least two sources of error. First, the value assigned to the spatial unit has an associated uncertainty. Second, even if the indicator value were known with certainty, there is uncertainty associated with the impact actually occurring within that spatial unit (Wickham et al. 1997).

In addition, individual indicators are not necessarily independent. Agriculture on steep slopes for example, is correlated with nutrient concentrations in freshwaters or with sediment loading to estuarine ecosystems. Spatial and auto-correlation will also be considered. For example, roads and particularly intersections of interstate highways are correlated with economic development activity, habitat fragmentation, and increased runoff from impervious surfaces. There does not appear to be any way to reduce the dataset to a subset of orthogonal indicators since, for example, the spatial network of roads is also needed as an indicator of routes for exotic species invasion and as barriers to dispersal between fragmented habitat patches.

Because risk assessment considers uncertainty, all sources of uncertainty must be retained. Measurement errors and correlations with other indicators are retained as a variance-covariance matrix. Coverages from statistical models have an associated goodness-of-fit estimate. Standard error analysis techniques will be used to estimate the uncertainty associated with coverages generated by process models. Research on combining uncertainty estimates for integrated rankings will be a high priority.

4.1.2 Step two

The second step will be the development of additional coverages derived from the primary spatial data. ReVA will employ three approaches.

The first approach follows the ecological risk assessment paradigm (USEPA 1998b). Spatial distributions of stressors, resources, and exposure indicators are overlapped to represent exposure (Figure 5). The second approach builds on the work of NERL’s Landscape Sciences Program (ESD) in developing and demonstrating the use of landscape indicators to assess ecological condition (Jones et al. 1997). The approach uses statistical models to estimate impacts on valued resources such as water quality and wildlife habitat. For example, this approach allows us to move from available spatial data on nutrient deposition, roads crossing streams, intact riparian zones, and agriculture on steep slopes to an estimate of risk of increased nutrient loading for every watershed across the region.

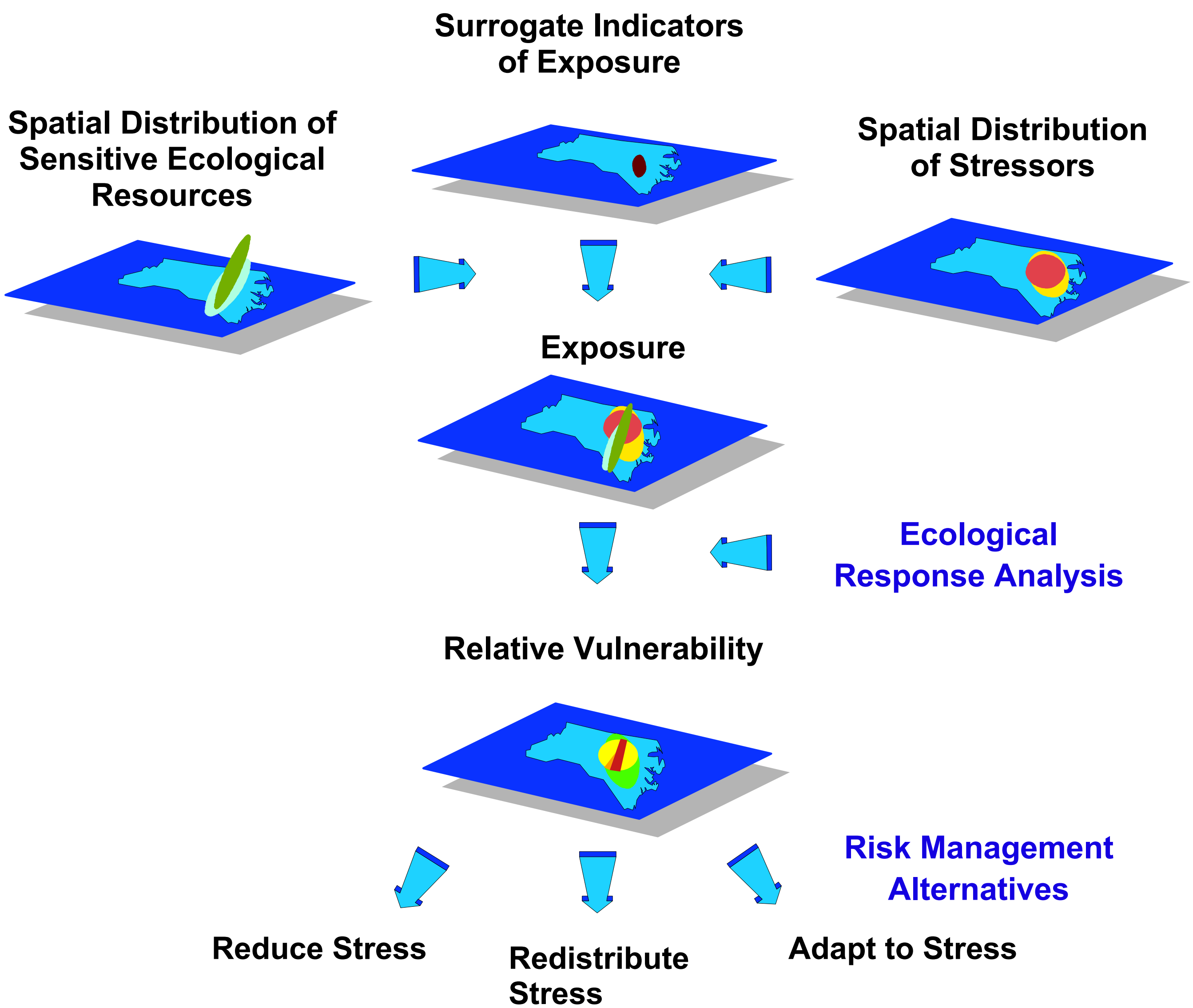


Figure 5. Overlay approach to estimate exposure and vulnerabilities.

The third approach uses spatial process models to extrapolate from point monitoring data to the spatial distribution of stressors. Examples include the estimation of atmospheric deposition (nitrogen, ozone, sulfate, and some toxics) using monitoring data from systems such as the Clean Air Status and Trends Network (CASTNet, see: http://www.epa.gov/ardpublc/acidrain/castnet/) combined with deposition models (e.g., Models3/CMAQ (Community Multiscale Air Quality), see: http://www.epa.gov/asmdner/models3), and known occurrences of aquatic non-indigenous species combined with geographic path analysis techniques to identify risk to native species. Survey and monitoring network data also will be used to formulate and test structured equation models using path analysis techniques.

Research will involve the development of models to link stressors to impacts on specific ecological resources. For example, metapopulation theory relates properties such as stability to the spatial configuration of a habitat. The theory can be used to relate changes in the spatial pattern of habitat to wildlife and endangered species. Development of such specific models would allow ReVA to translate fragmentation indicators into indicators of potential impact on specific species. All models used or developed by ReVA will be evaluated through sensitivity and error analyses. Where multiple models representing the same process or relationship are available, results will be compared as to where they agree or disagree and an assessment of these differences will be made and documented.

4.2 Integration and Evaluation

Information must be integrated across response variables and stressor distributions to assess overall environmental condition (Wickham et al. 1999). This synthesis is a complex process with many challenges and developing the appropriate methodologies is a high-priority research task in ReVA. The integration methods developed and employed by ReVA will be evaluated as to sensitivities to different data issues (e.g. continuous or noncontinuous data, skewed distributions) and to small changes in variables, and to the ease of use and understanding by the user.

Perhaps the most easily understood integration method is the weighted-sum approach (e.g., Wade et al. 1995). Condition is the sum of the component indicators, weighted by their importance. Relative importance, however, involves subjective judgment. The National Park Service may have a very different view of watershed vulnerability than the state planner responsible for economic development. The weighted sums algorithm has the flexibility to allow the decision-maker to vary the "importance" weights associated with individual indicators and develop individualized overviews of vulnerability.

Another evaluation approach might consider the risk of crossing thresholds established by federal law. This approach would use a suite of indicators to estimate the risk that a particular assessment unit was in violation of the endangered species act, the Clean Water legislation, etc. Areas in potential violation of statutes or regulations could then be identified for further study.

A third assessment approach might be to represent each indicator value as a point in a multivariate state space (Johnson 1988). The measure of vulnerability is then calculated as the Euclidean distance to the closest region of "unacceptable impact." This approach would also be valuable in identifying the magnitude of change in specific indicators that would produce the greatest reduction in risk. A measure of current environmental condition could also be calculated as the distance between the present state and an optimal point defined as the ideal or desired environmental condition.

The state space approach has the advantage of easily accounting for errors in both site and reference measurements. The approach uses a measure of distance derived from Fuzzy Set Theory (Zimmerman 1987, Tran and Duckstein, 2002). This theory was developed by Zadeh (1965) to deal with problems resulting from "fuzzy" or uncertain data. Each measured value is described by an interval, for example, the mean plus and minus a standard deviation. The site measurements and the reference site are represented by a "fuzzy" circle or polygon in the multidimensional state space. In essence, the distance measure integrates all the distances, from the nearest to the furthest, between the site and the desired state.

The state space approach can also account for codependencies among the indicators. In the usual representation of a Cartesian space, the axes meet at right angles and assumes that the variables are independent of each other, i.e., a correlation coefficient of 0.0. If the coefficient is 1.0, the two axes overlay each other since two metric values would represent different measurements of exactly the same thing. It follows that covariances can be represented by the angles between the axes. For example, a correlation coefficient of 0.5 would be represented by an angle of 45 degrees. Once the original Cartesian state space is modified, using the calculated covariance, the "fuzzy" distances can be calculated for this transformed space.

A similar approach can be taken using multivariate statistics. The statistical calculations are based on the variance-covariance matrix and therefore directly account for measurement errors and codependencies. This method estimates the probability that a site has departed significantly from the "natural" reference site and/or that the site is no longer significantly different from the "degraded" reference site.

ReVA will also explore methods such as multiple objective decision theory (Hipel 1992), artificial intelligence (Rauscher and Hacker 1989), and spatial information integrating technology (Osleeb and Kahn 1999).

Risks also can be estimated for economic objectives. This approach would directly consider the viewpoint of a decision-maker responsible for economic development in the region. In general, the attractiveness of a specific geographic location to development and investment is determined by socioeconomic factors such as available labor, power, transportation, etc. But decisions are also based on the environmental condition of the location, involving factors such as clean air and water, available recreation, scenic values, etc. The ReVA indicators could be integrated into a overall estimate of the extent to which the economic attractiveness of an area might be degraded by environmental impacts. Such an overview would be invaluable to decision-makers in setting planning and restoration priorities and developing landuse plans for zoning and other available planning tools.

4.3 Developing Alternative Future Scenarios

The development of alternative future scenarios is an important component of ReVA. Future scenarios will include increases in human population (e.g., Campbell 1997) with its associated increases in pressures on the environment (e.g. air deposition, hydrologic modification), continued urban development (Knox 1993), and climate change (Watson et al. 1996). Future scenarios for the Phase One assessment will focus primarily on extrapolating changes in land use but will also estimate potential changes in spatial distribution of pollution, non-indigenous species (NIS), and resource extraction to examine potential impacts to water quality, human health, etc.. Future scenarios for Phase Two will incorporate projected land use changes as well as anticipated changes in other stresses (e.g., air emissions, spread of NIS, projected resource extraction) and changes in regional weather patterns and will be developed by predicting likely changes in socio-economic drivers over the next 20-25 years.

A particular problem is posed by extrapolating land use changes. For example, population growth can result in conversion of land to residential and agricultural uses (Wheeler et al. 1998). Distributing these changes spatially will be critical to projecting changes in stresses such as aquatic non-point source pollution (e.g., percent impervious surface or agriculture on steep slopes) and forest productivity. Land use changes can also directly alter estimates of resources (e.g., wildlife habitat, Browder et al. 1989).

The development of land use change models is an important research area. ReVA has already sponsored development of several models and techniques for projecting land-use change at the regional scale. These range from simply documenting plans for highway construction and new employment centers across the Mid-Atlantic region, to estimating land demand from state census projections, to customizing applications of a traditional resource economics model (Hardie and Parks 1997) and a state-of-the-art cellular model of urban growth (Clarke et al. 1997). The intent is to compare projections resulting from different modeling paradigms to determine, through weight of evidence, the most likely regional growth centers.

Work is also proceeding in-house to integrate attributes of the resource economics model and projected highway construction into a new cellular growth model that incorporates the drivers and data from multiple approaches. ReVA has initiated a thorough inventory and evaluation of the leading land-use change models currently in use or under development (USEPA 2000). This report examines 22 models and permits ReVA to identify appropriate models for projecting future scenarios at various resolutions, and to target new research where gaps exist in modeling scales, land-use types, and conceptual approaches.

For the Phase Two assessment, changes in stressor amounts and distributions will be estimated by: 1) surveying EPA's program offices to evaluate the current thinking on what are estimated future trends in pollution loadings and pollution prevention; 2) surveying regional stakeholders for future issues associated with increasing population and development pressures; and 3) sponsoring workshops of experts to develop alternative future scenarios based on a combination of estimated changes in population numbers, demographics, behavior and resource utilization.

ReVA is sponsoring research under the National Center for Environmental Research's (NCER) Science to Achieve Results (STAR) program to identify anticipated changes in socio-economic drivers and likely changes in human pressures on the environment (see Request for Applications (RFA) at: www:epa.gov/ncerqa). ReVA will work closely with NERL's Environmental Sciences Division and EPA's Office of Environmental Information (OEI) in the development of a joint EPA/US Geological Survey effort to develop a "Driving Forces of Land Use Change University Consortium." Stakeholders in communities will also be queried as to likely responses to projected land use change so that a variety of alternative scenarios can be developed that will reflect management options to achieve a range of potential management goals and alternatives.

As future scenarios are developed, the challenge is to translate the projected scenario into spatial changes in stressors and resources. In most cases, the changes can be extrapolated using the same models used in the assessment of current conditions. For example, population growth and urbanization will result in increased SO_2 that can be distributed spatially by the same air diffusion models. The most difficult task involves translating socioeconomic drivers into land use change. One approach will combine models from economic geography and statistical analysis to determine the probability of a pixel changing to agricultural or residential land use. The underlying geographic theory states that the probability of change will be determined by the access to roads (i.e., cost to transport products) as well as distance and size of accessible urban markets (Wickham et al.2000).

Another approach is based on an analysis of landscape sensitivity to fragmentation (Riitters et al. in review). Some landscapes are more sensitive (to the loss of resource area) than others, owing to differences in the spatial arrangement of their component resources. Models predict the likelihood of fragmentation as a result of different degrees of land-cover change in different spatial patterns of driving forces (e.g., roadbuilding versus urban sprawl). Continental maps of current fragmentation sensitivity (in progress) measure the relative risks already taken by historical patterns of land use. Sensitivity can be re-evaluated for any future scenario and map of land-cover change, including local remediation, to estimate the likely regional impacts on fragmentation-sensitive resources. The models have been developed by using the Multi-Resolution Land Characteristics (MRLC) land-cover maps but the general procedure can be tuned for other data sources and scales.

Once the scenario is translated into spatial changes in stressors and response variables, the regional assessment can proceed with the same approach used in assessing current vulnerability. The result will be an overview of the impact of the proposed changes on environmental condition of the Region. This will make possible a comparison of pre- and post-scenario overviews including the identification of areas that are at greatest risk of degradation under alternative scenarios. These areas, therefore, might be the most vulnerable and targeted for risk management activities.

4.4 Technology Transfer and Communication

In most cases, the results of an assessment are finalized as a report or journal article that is of limited use to the individual decision-maker. ReVA will expand its focus to include products that have broader application and will work directly with clients to develop tools that will support environmental decision-making. The nature of a more broadly applicable output can be illustrated with an example of the Weighted Sums approach to assessment. The final step in this algorithm involves the user choosing a weight for each of the indicators, i.e., how important each individual stressor or impact is to overall environmental condition. In a formal report, these weights might be chosen based on the best available scientific opinion on relative impacts.

Clearly, opinions on the relative weights will vary with the end-user. A state planning agency might be most concerned with indicators that might diminish the potential for economic development. A conservation agency might be most concerned with indicators that might degrade an area set aside for preservation. A regulatory agency might be most concerned with indicators that reflect potential violations of legal limits. So there is no one set of weights that maximizes the utility of the regional assessment database and the assessment algorithm. Therefore, the weighted sums model might be loaded on a CD that can be placed in an envelope inside the back cover of the final report. The CD would contain the instructions and software to access the ReVA database, manipulate the weights placed on different indicators, and provide output that is tailored to the user's application. ReVA will also make the data sets and algorithms available on the internet so that individual decision-makers can tailor the assessment to specific planning needs.

Communicating results in terms of how they affect people’s quality of life is an important task for ReVA. The application of resource valuation and quantification and communication of both the social and economic costs and benefits of alternative decisions will allow better environmental accounting and will illustrate the ecological implications of society’s actions. These efforts will be accomplished in Phase Two.

ReVA will also support the development of guidelines for the different aspects of assessing regional vulnerability. Guidelines will likely be developed for 1) information management; 2) data quality assessment, diagnostics, and transformation for statistical integration; 3) use of different integration methods; 4) future scenario development; 5) multi-criteria decision-making; 6) identifying priorities for risk management; and possibly others.

4.5 Demonstration of Finer-Scale Applications

Recognizing that most environmental decision-making occurs at scales that are less than regional, ReVA will partner with stakeholder groups to develop and demonstrate applications of local scale decision-making. These demonstrations will occur concurrently with the regional scale assessment as they can provide useful feedback that will improve the overall assessment product. Stakeholder groups may include non-governmental groups (e.g., the Canaan Valley Institute), county planning organizations (e.g., Baltimore County), or private institutions (e.g., the Water Environment Research Foundation) that are interested in developing decision-support tools that enhance local planning or restoration efforts. An example is the development of a restoration tool that uses decision-tree analysis to identify and prioritize areas for riparian reforestation based on attributes associated with erodability and reducing sediment loads, habitat enhancement and regional connectivity for migratory species, aesthetics and wetland protection. ReVA will provide data and technical assistance in the use of regional scale information for these demonstrations. It is expected that the tools developed will use a combination of regional scale information along with finer-scale models that provide additional detail. An evaluation of how these data and models work together may provide insights into the issue of scale and identifying the limits of how far fine-scale information can be extrapolated and how far regional scale information can be drilled down to answer local management questions.

Section 5
Schedule and Products

5.1 Annual Performance Measures

ReVA has identified the following (Table 2) Annual Performance Measures (APMs) in accordance with the Government Performance and Results Act (GPRA) of 1993.

Table 2. APM Titles.

FY	APM Title
2003	Complete an assessment estimating the comparative vulnerability of forests and small streams in the Mid-Atlantic region of the United States to multiple stressors, including land use change, atmospheric deposition, resource extraction, agricultural runoff, and invasive, non-indigenous species.
2004	Decision-support tool for Mid-Atlantic that enables assessment of impacts associated with alternative land use, air deposition, and resource extraction scenarios as determined by client.
2006	Complete an assessment of the regional sustainability/vulnerability of ecosystems in the Mid-Atlantic region of the United States; provide decision support tools for risk reduction activities.
2008	Complete an assessment of the regional sustainability/vulnerability of ecosystems to local, regional, and national stressors, now and in the future; demonstrate cost-effective adaptation and mitigation technologies for watershed and regional systems in the Mid-Atlantic region of the United States and in one additional region.

5.2 Milestones for the Phase One Assessment

Task	**Date**
ReVA Strategy Peer Review	February 2001
Final ReVA Strategy	January 2003
Phase 1 Spatial Data Compilation Complete	March 2002
Evaluation of Integration Methods	March 2003
Future Scenarios Developed	May 2003
Draft Report NERL Review	August 2003
APM Mid-Atlantic Forest and Streams Vulnerability Assessment	September 2003

5.3 Products

- Decision-support systems that use remote sensing, GIS, and predictive modeling for prioritizing issues and management actions
- New indicators for measuring cumulative effects, ecosystem vulnerability, and changes in quality of life
- Techniques for incorporating ecosystem assessments and valuation in policy decisions
- Improved models that forecast changes in ecosystem resiliency and the capability to support living resources
- Identification of gaps in information and knowledge to refine monitoring and prioritize research
- Methods to integrate ecosystem, social, and economic data to illustrate trade offs associated with alternative policy choices

5.4 Measures of Success

ReVA is committed to establishing specific measures of success for the program, and to continuously gauge the program against those measures and refine it as needed. Though work is needed to define the measures, the following outline highlights key elements.

5.4.1 Customer perspective

- Use of ReVA-generated information in accomplishing the customer's mission
- Satisfying customer needs and expectations
- Building a broad-based constituency for the program
- ReVA approach incorporated in the customers programs

5.4.2 Science perspective

- High quality science as reflected by frequent and critical peer reviews and publications in professional journals
- Continued incremental improvement in accomplishing scientific and technical program objectives

5.4.3 Management and operations perspective

- Research deliverables accomplished within cost and on schedule
- Managers and technical staff desire to participate in the program and see it as a career opportunity
- Program enhances inter-organization cooperation in key areas such as risk assessments, risk reduction, regional planning and ecosystem management

Section 6

Relationships to Other Programs

ReVA is an integral part of the programs being conducted in EPA Region 3, including the Mid-Atlantic Integrated Assessment (MAIA) geographic initiative (Figure 3). As part of the USEPA Region 3 MAIA initiative, a set of assessment questions have been developed through interactions with various stakeholder groups. These questions represent the problem formulation stage of the risk assessment process. These questions also reflect environmental issues and problems raised as part of the EPA Region 3 strategic planning process. Although ReVA is only a part of the entire assessment process, it will contribute to answering the following regional assessment questions:

1. What abiotic and biotic factors are associated with environmental effects (condition) in the Region?
2. What are the relative rankings of regional stressors?
3. Where are the "hotspots" of poor condition in the Region?
4. What are the differences between areas with good versus poor condition?
5. What are the socioeconomic factors contributing to stressors and condition?
6. What are socioeconomic and environmental costs and benefits associated with alternative management programs?
7. What are the trade offs associated with alternative management programs?
8. Which environmental problems are putting the Region at greatest risk?

Within MAIA, the EMAP Program provides information on the condition and trends in ecological resources, including monitoring information. ReVA builds on this and other monitoring data (USDA Forest Health Monitoring (FHM) Program, USGS National Water Quality Assessment (NAWQA) program, USFWS National Wetlands Inventory, and NOAA Status and Trends Network, Multi-Resolution Landscape Characterization (MRLC)), and integrates it with spatially explicit models of stressor distributions, and surrogate indicators of exposure (developed from monitoring data) to map multiple exposures affecting regional resources and the sustainability of ecological goods, services, and other benefits. Using this information, ReVA will develop the tools and approaches to assess the current and future ecological vulnerability of systems within the region (Figures 3 and 4).

As stated under the General Approach Section, ReVA will also consider alternative futures that might occur with land use changes and associated stresses such as non-point source pollution and atmospheric deposition and how the ecological vulnerability of systems might change with different patterns of land use. These current and future estimates are critical for the Mid-Atlantic Regional Assessment (MARA) of Global Climate Change being conducted by The Pennsylvania State University researchers and collaborators under the US Global Climate Change Program. Changes will occur in the Mid-Atlantic region regardless of whether global climate change occurs. Having information on projected changes then provides the base for assessing additional changes that might occur because of climate. Similarly, ReVA will use projections of changes in regional weather patterns developed under MARA.

Both scientific and management program interactions will be fostered by ReVA. Within EPA, for example, ReVA has been interacting with the EMAP Program for information on status and extent of ecological resource condition at large spatial scales, indicator development and testing, and association analyses. The NERL Landscape Sciences Program is conducting research on landscape indicators, their association with ecological resource condition, and remote sensing of these indicators. ReVA will build on this information foundation in developing and evaluating assessment techniques and tools for conducting assessments at large spatial scales. In addition, ReVA is closely interacting with NCEA to identify gaps in existing assessment tools and areas of needed research, and to evaluate and test local scale assessment procedures that appear to be applicable at broader scales. ReVA also is working with, and has funded, scientists in universities and other agencies to conduct research on issues ranging from NEXRAD radar tracking of migratory birds to determine areas for protection along the migratory routes to assessing the vulnerability of regional aquatic ecosystems to non-indigenous species introductions.

ReVA is also interacting closely with MAIA, Region 3 Divisions, and Program Offices to identify large-scale issues which existing technology and tools are not adequately addressing. ReVA is represented on the ORD MAIA Steering Committee. In addition, ReVA is working with the USDA Forest Service on forest fragmentation and other management issues that affect the sustainability of forest productivity and health.

Some of the other collaborative interactions that have, or will, occur with other offices, agencies, and organizations are listed in Table 2. Many of the tools, approaches, and demonstration assessments being developed by ReVA will provide perspective for many other activities including selection of high priority areas for protection and restoration within the region, evaluation of spatially-based biological criteria, development and refinement of regional comparative ecological risk assessment, and smart-growth initiatives such as potential siting for transportation corridors.

ReVA has developed and will sustain outreach activities to ensure that new opportunities for collaboration will be identified and new applications for its tools and approaches can be tested through MAIA and in other regions in the future.

Table 3. Potential Interprogram and Interagency Interactions with ReVA.

Program/Organization	Opportunity
EPA -NHEERL -EMAP	Additional indicators for Western Pilot important for ReVA's national implementation; suggestions for improved monitoring based on hierarchical stratification reflecting sensitivity to stress.
EPA - NCEA	Enhancements to Ecological Risk Assessment Guidelines.
EPA - NRMRL	Decision-support tools, prioritization of areas for risk management/reduction
EPA - NCER	Relevance of RFA, grants and cooperative efforts to ReVA (See NCER Web Site).
EPA - Office of Water	Spatially-based biological criteria with management implications. Water and vulnerability indicators added to "Surf Your Watershed". Identification of sensitive watersheds.
EPA - Office of Air and Radiation	Impact of future emissions; identification of sensitive watersheds/ecoregions.
EPA - Office of Prevention, Pesticides, and Toxic substances	Spread of NIS and implications for pesticide use; impacts of agricultural inputs on water quality.
MAIA	Improved assessment technologies. Future scenarios to illustrate alternative choices. Partnerships with stakeholders for application development.
Region 4 Ecological Assessment Program (REAP)	Evaluation and refinement of methods developed in R 3.
Global Change Program	MARA and SE assessments.
Committee on the Environment and Natural Resources	Approach used in National Report Card. Interagency collaboration and demonstration of ISEC and ecological forecasting.
USGS Water Resources Division	Scaling issue studies, spatial and temporal data access. Improved assessment methods.
USGS Biological Resources Division	Spread of NIS, identification of vulnerable resources for conservation planning.
FWS, USGS-BRD, NRCS	Wetland studies, metrics, and spatial data access.
BLM, USDA-FHM	Range land characterization and spatial coverages. Future risk to forest health.
NPS, FWS Reserves	UV-B and amphibian monitoring data; threats to T&E species.
TVA	Application development, communication to stakeholders, future ming impacts.
The Nature Conservancy	Regional implications of TNC conservation/ preservation spatial areas; information on existing biodiversity.
Center for Transportation and Environment	Transportation corridor planning-spatial coverage.
National Association of Professional Planners	Planning workshops–stakeholder input and proposed areas of development.

Section 7
Management Structure

7.1 Cross-ORD Structure

ReVA's management structure is designed to enhance coordination across ORD and to ensure that the needs of clients (who include EPA Program Office and Regional decision-makers) are addressed as well as to take advantage of available information and expertise (Figure 6). The National Exposure Research Laboratory (NERL) has the administrative responsibility for the development and management of ReVA. As ReVA represents a significant contribution to the ORD Ecological Research Strategy, oversight for the development and management of ReVA will be done by a Steering Committee composed of ORD's four Associate Directors for Ecology, representing NERL, the National Health and Environmental Effects Research Laboratory (NHEERL), the National Risk Management Research Laboratory (NRMRL), and the National Center for Environmental Assessment (NCEA).

A Program Office Review Committee has been established to provide an opportunity for EPA Program Offices to review ReVA's progress and to provide feedback. This committee consists of one or two representatives from each EPA Program Office and it is anticipated that the committee will meet once a year with the ReVA Program Director to review plans and products. The ReVA program director also is responsible for keeping this committee updated as to developments and changes in program direction.

An ORD Planning Committee has been established for ReVA to help prioritize needed research, to identify opportunities for cross-laboratory collaboration, and to review budget decisions. This committee consists of representatives from NHEERL, NRMRL, NCEA, NERL, and NCER and a representative from Region 3.

7.2 ReVA Program Structure

Experience with large-scale assessments in the past has helped guide the management structure of the ReVA program (Figure 7). The ReVA central team will be headquartered in NERL at facilities in Research Triangle Park, NC. All planning and management activities for ReVA will be the responsibility of the central team. This central team will consist of the program director, a Post-Doctoral fellow assigned to the program director, the lead for the Applications team and the lead for the Research team. There will be one primary ReVA contact person at each remote laboratory site.

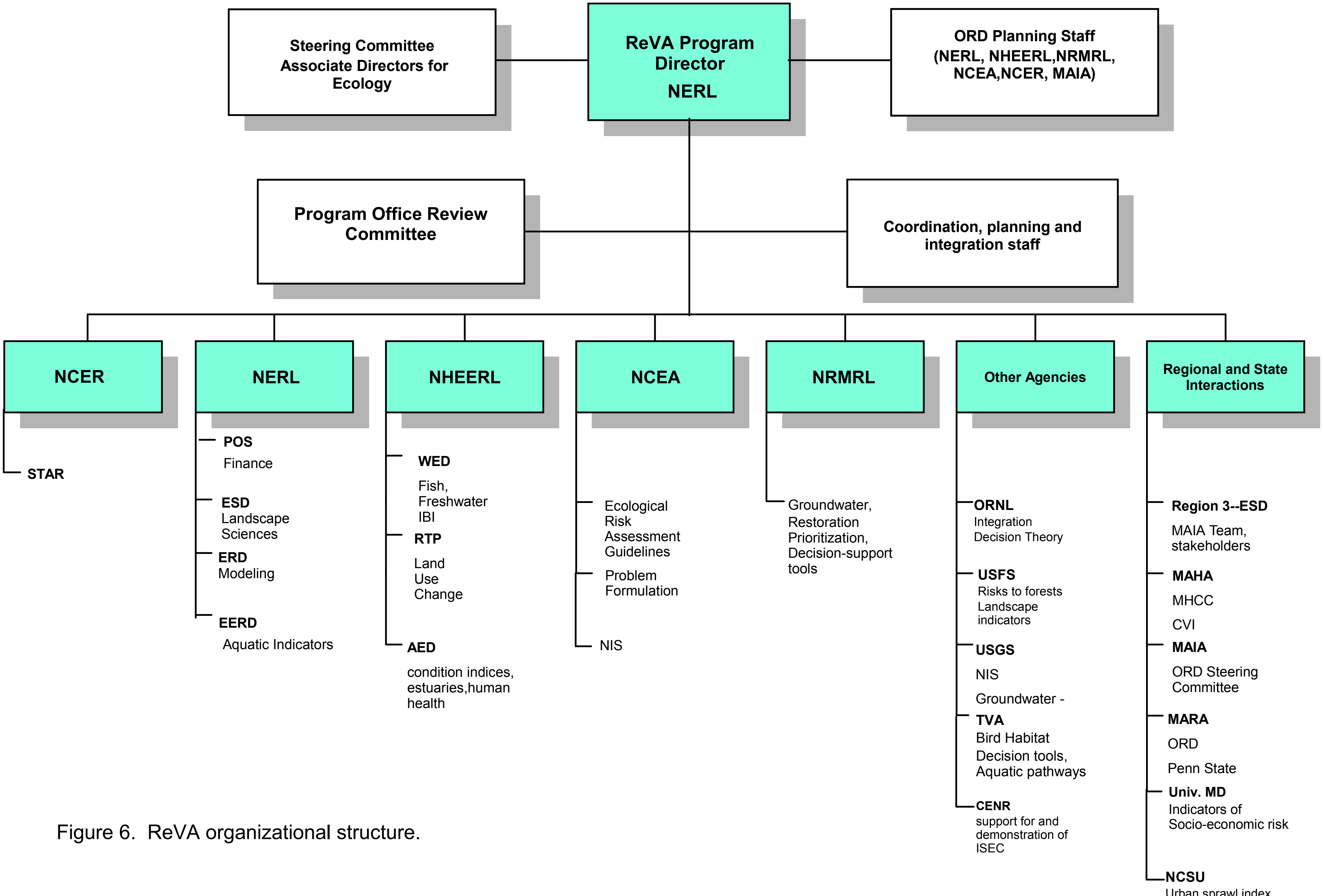


Figure 6. ReVA organizational structure.

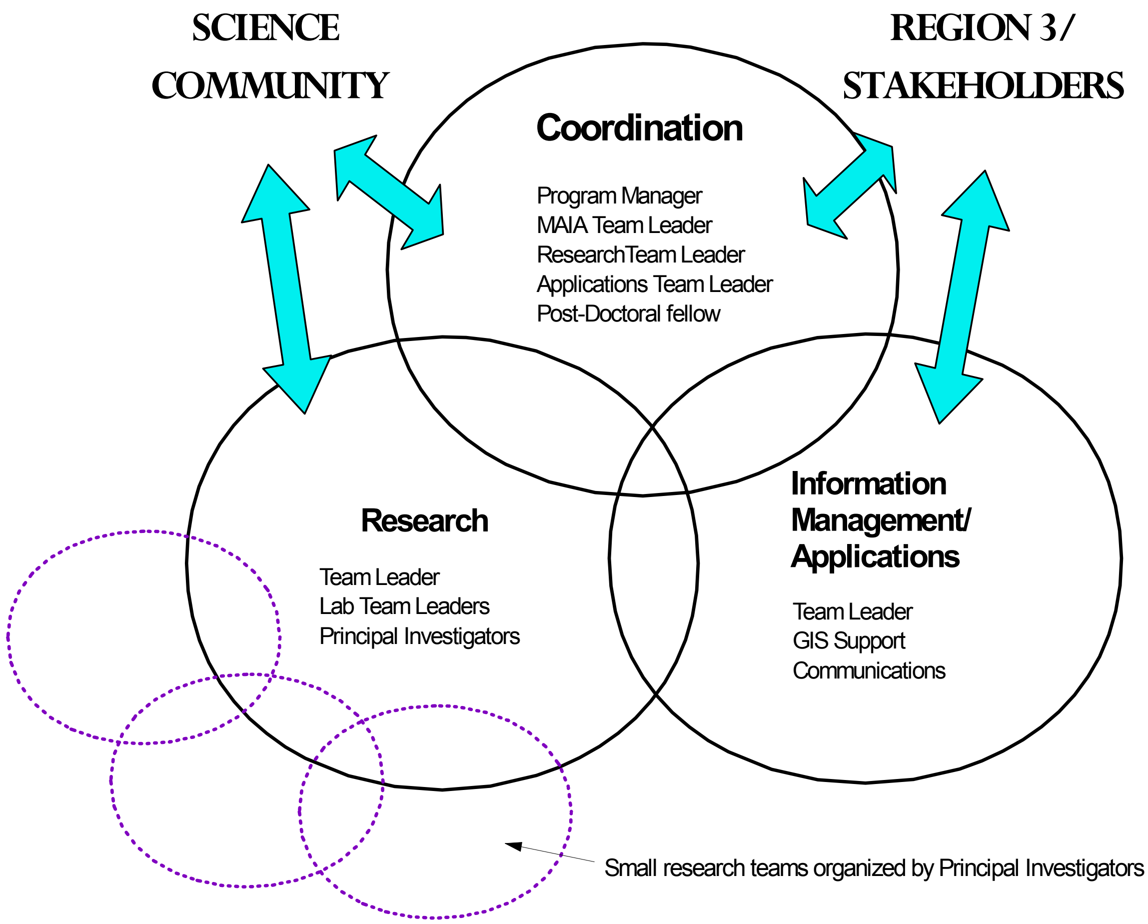


Figure 7. ReVA program structure.

An Applications/Information Management team has been established to facilitate data sharing among all the remote sites and with non-EPA partners and to provide general GIS support in the development of integrated research products. Based on past experience, it has been recognized that an applications team can improve overall efficiency through serving as a clearing-house for interim products and requests for information from clients. This will lessen disruption of progress by allowing the principal investigators to focus on their research while the applications team is responsible for maintaining on-going service to, and communications/feedback with our clients. IM representatives from all the remote sites will work with the RTP Applications team in the development of an information management plan and data policies. Databases used in all ReVA projects will be stored and made available through ORD's Environmental Information Management System (EIMS). (See section on Information Management below).

In addition to the Applications team, the central ReVA program will establish a Core Research Team. The Core Research Team will have responsibility for program goals in indicator development, integrated assessment, future scenarios and technology transfer. In some cases, the Core Research Team will undertake independent research in an effort to fill gaps needed to fulfill program goals. In the majority of cases, the Core Research Team will operate as collaborators and co-investigators in projects with other ORD programs, such as EMAP or the Global Change Program, in projects with the laboratories participating in ReVA, and in projects with other federal agencies. The Core Research Team plays a critical role in the ReVA structure since this small central group will have hands-on experience with all facets of the dispersed research program.

7.3 ReVA Information Management and Data Policies

Adherence to management principles and establishment of a management plan are vital to the success of any program While these involve a significant level of up-front effort, the aim is to alleviate future problems. Nowhere is this more important than in the case of information and data management. By establishing a common understanding of what data are available, where they are stored, how they are maintained, and how they can be accessed, ReVA intends to ease the individual researcher's burden for information management. These information management practices and data policies will be further elaborated in a separate document that is currently under development. General policies for information management include:

1) Adherence to Federal Geographic Data Committee (FGDC) metadata standards for all spatial data sets. Additional metadata documentation will likely be suggested for derived databases to document uncertainties and errors associated with sequential steps in developing regional scale models. FGDC metadata standards can be found at: http://www.fgdc.gov/metadata/csdgm/.

2) Use of a central metadata server to facilitate use of available data among all ReVA PIs and to ensure use of the same versions of these data. ORD's Environmental Information Management System (EIMS) is an Oracle-based relational database system used to store and retrieve metadata information regarding EPA products. While the actual locations of the information objects may be distributed, having a common source from which to search for available information will provide researchers with a powerful tool. It should be noted that EIMS is equipped with security features that allow differential access control to all its documents, by originator, group, EPA or the public. EIMS can be accessed at: http://www.epa.gov/eims or through ReVA's website: http://www.epa.gov/reva.

3) Use of Terrasoar as ReVA's spatial data warehouse. While the metadata for spatial products will be available through EIMS, a system called Terrasoar, because of its unique search, browse, and ordering capability, will serve as the data warehouse for ReVA spatial data. Terrasoar can be access at: http://epawww.epa.gov/j02remsn/download.html. (Note: Terrasoar is currently only available for internal EPA use, however links between Terrasoar and EIMS are envisioned in the future.)

4) Establishment and support for the following goal regarding an exclusivity period: "Research products developed with support from the ReVA program will be deemed limited access for a period of one (1) year, during which researchers will perform all the necessary tasks required for publication. The term limited is intended to convey access by the ReVA core team and other ReVA principal investigators while disallowing overall public access. Providing limited access during the first year allows ReVA to continue progress in integrating the various and disparate areas of research into a cohesive assessment while not compromising the intellectual investments made by individual researchers. After one year, data will be made available to the

public."   While our goal is to make data available as soon as possible, ReVA will adhere to ORD and/or agency policies regarding data exclusivity.

Section 8
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Appendix A
Summary of Tasks

ReVA Proposed Task Description Format

Date of Update:

Task Title:

Abstract: *one paragraph, written for lay reader as this will go on the ReVA website if funded*

Objective(s) of Task: *bullets*

How Task Relates to ReVA Research Objectives: *list specific ReVA research objectives that will be addressed by this research and briefly explain how the research will help ReVA achieve these objectives and goal.*

Linkages to Other ReVA Tasks: *e.g. if this research improves ability to estimate distributions of stressors or sensitive resources, which models can be used to estimate current and future vulnerabilities; if this research will result in a new effects or risk model, are there other ReVA tasks that will provide the basis for looking at relative risk for a ReVA endpoint over a region?*

Approach: *short description of how task objectives will be accomplished*

Data Sets Used: *source, scale, extent, FGDC metadata-compliant?*

New Data Collected: *list data sets that will be assembled*

Quality Assurance: *should include plans for documentation of error/uncertainty in data used or collected, and how error and uncertainty (including error propagation for derived datasets) will be documented for results*

Activities by Fiscal Year: *should show clearly the progression of the research and if there are opportunities to use interim results*

Progress and Products to Date: *peer reviewed publications, presentations, data or models that can be used in the ReVA Phase 1 assessment*

Deliverables: *Specific GIS coverages along with units represented (e.g surface maps, by 8-digit HUC, ecoregion), predictive models, etc.*

Evaluation of Results: *using peer review process, weight of evidence, other?*

How Outcomes Can be Extended to Other Regions: *are results directly applicable, or can the approach be adapted for other regions if data are available?*

How Outcomes Can be Made Available to Clients: *can outcome be applied directly by clients or does it require development of guidelines or other tech transfer/ training? What mechanism is suggested for making available to clients (e.g. internet, incorporation into a decision-support tool)*

List of Clients: *should be clear what is level of decision-making (regional, community, research community)*

Major Collaborators: *EPA ORD researchers, universities, other agencies*

Budget Request By FY: *through the end of the project. Should be able to link with yearly activities and deliverables*

Task Title	Principal Investigator	Division/Org	Contribution to Objective	Phase Report		Research Category			
				1	2*	Stressors	Receptors	Exposure Assessment	Communicat-ing Results
Regional Scale Comparative Risk Assessment	Betsy Smith	ESD	all	✓					
Information Management	Vasu Kilaru	ESD	all	✓					
Land Use Change Modeling	Ron Matheny	ESD	3	✓		risk of development			
Geostatistical Modeling of Sulfur and Nitrogen Deposition	David Holland	ESD	1,3	✓		air deposition			
Development of Landscape Indicators for Use in Regional Ecological Risk Assessment	Bruce Jones	ESD	2	✓		increased development	water quality; forest & streams habitat	exposure model	
Consequences of Landscape Change in the Mid-Atlantic	Bruce Jones	ESD	2,3	✓		increased development	water quality; native species	exposure model	
Quantification of Landscape Indicators/Water Quality Relationships in MAIA	Bruce Jones	ESD	2,3	✓		increased development	water quality	exposure model	
Riparian Habitat Indicator Development	Bruce Jones	ESD	1,2	✓		increased development	native species	exposure model	
Applications of Fuzzy Logic in Estimating Landscape Indicator Values	Bruce Jones	ESD	2,5	✓				exposure model development/ integration	quantifying risk

Task Title	Principal Investigator	Division/Org	Contribution to Objective	Phase Report		Research Category			
				1	2*	Stressors	Receptors	Exposure Assessment	Communicat-ing Results
Landscape Indicator Development for Watershed Risk Assessment for Pesticides and Toxic Substances	Ann Pitchford	ESD	2,3,5	✓		pesticides	water quality; native species; designated use	exposure model	
Atmospheric Ecosystem Stressor Pattern and Trend Analysis	Joe Sickles	ESD	1,3	✓		air deposition			
Landscape Characterization: MRLC Coordination	Jim Wickham	ESD	1	✓		risk of development	water quality	N+P loading; exposure model	
Use of Fuzzy Logic to Integrate Disparate Data	Liem Tran	Penn State	2,4	✓				integration	quantifying risk
Projected Land Use and Land Cover Change for the Mid-Atlantic Integrated Assessment	Sandy Bird	ERD	3	✓		probability of change	water quality; native species	exposure model	
Regional Vulnerability Assessment of Streams	Susan Cormier	EERD	4,5		✓		water quality; habitat		
Landuse Change Under Alternative Future Scenarios	Laura Jackson	NHEERL	3	✓		risk of development	all	exposure model	
Predicting Freshwater IBI	Tony Olsen	NHEERL	2,3	✓		risk of development	native species; water quality	exposure assessment	
Natural and Anthropogenic Factors Affecting Freshwater Fish species Diversity	Denis White	NHEERL	2	✓			native species		

Task Title	Principal Investigator	Division/Org	Contribution to Objective	Phase Report		Research Category			
				1	2*	Stressors	Receptors	Exposure Assessment	Communicat-ing Results
Prioritization Analyses for Conservation of Fish Species	Denis White	NHEERL	1	✓			native species		
Vulnerability of Aquifers to Trace Metals in the Mid-Atlantic Region	Bart Faulkner	NRMRL	2	✓		toxics	Groundwater	exposure model	
Decision-Support tool for Assessing Groundwater Vulnerability to Pesticides	Joe Williams	NRMRL	1,4		✓	pesticides	Groundwater	exposure model	
Decision-Support tool for Prioritizing Areas for Restoration	Joe Williams	NRMRL	5		✓		water quality; habitat		risk management
Assessment of Groundwater Vulnerability	Joe Williams, Bob Shedlock	NRMRL, USGS-WRD	1,4		✓	increased development	Groundwater	exposure model	
Regional Risk Assessment of Non-Indigenous Species	Jim Andreasen	NCEA	1,5		✓	NIS - terrestrial	native species	exposure model	
Vulnerability of Forests to NIS and Other Stressors	Kurt Riitters	USFS	1,2,4	✓		NIS; air deposition	health; native species	exposure model	
Identifying Stopover Locations for Neotropical Migratory Birds	Roger Tankersley	TVA	1,3,4	✓		increased development	native species	exposure model	
Strategy to Incorporate Socio-Economics into the Regional Vulnerability Assessment	Lisa Wainger	U MD	4	✓				integration	cost/benefit of alt. policies
Advancing Economic and Ecologic Indicators for Regional Risk Assessment	Lisa Wainger	U MD	4	✓				integration	cost/benefit of alt. policies

Task Title	Principal Investigator	Division/Org	Contribution to Objective	Phase Report		Research Category			
				1	2*	Stressors	Receptors	Exposure Assessment	Communicat-ing Results
Development of Urban Sprawl Index	George Hess	NCSU	4	✓		increased development			
Predicting Probability of Impacts from Chip Mills and OSB Mills	Rex Schaberg	Duke	1,3	✓		resource extraction			
Development of Species Distribution Database	Larry Master	Association for Biodiversity Information	1	✓			native species		
Strategy for Communicating Ecological Risk to Lay Audiences	?	NCEA	4						communicating risk

*Phase 2 Report will include Report 1 items

Appendix B

Current Members of ReVA's Program Office Review Committee

Denice Shaw	Office of Environmental Information (OEI)
Donald Rodier	Office of Prevention, Pesticides and Toxic Substances (OPPTS)
Laura Gabanski	Office of Water (OW)
Mary Reiley	Office of Water (OW)
Melissa Mccullough	Office of Air Quality Planning and Standards (OAQPS)
Pasky Pascual	Office of Science Policy (OSP)
Richard Haeuber	Office of Air and Radiation (OAR)
Vicki Sandiford	Office of Air Quality Planning and Standards (OAQPS)

Appendix C

Current Members of ReVA's ORD Planning Committee

Rochelle Araujo	NERL
Patricia Bradley	MAIA Team
Jeff Frithsen	NCEA
Steve Hedtke	NHEERL
Barbara Levinson	NCER
Joe Williams	NRMRL